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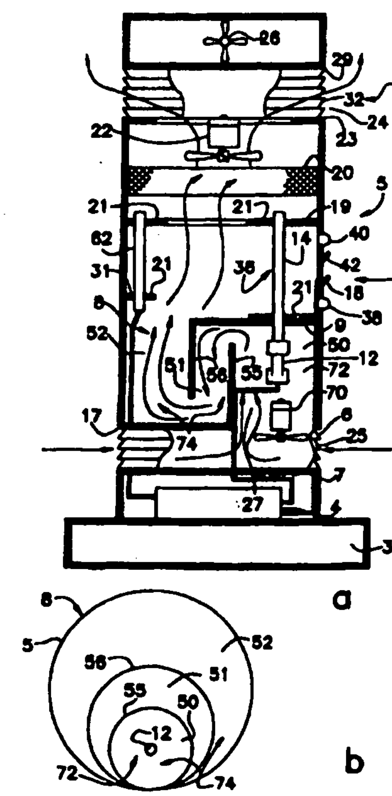
(54) Title: METHOD AND APPARATUS FOR STERILIZING AIR

(57) Abstract

An air sterilization system (2) is accomplished by exposing an incoming air stream from a surrounding area to ultra-violet (UV) radiation to generate ozone in an ozone chamber (8) of the system. The ozone chamber (8) includes a tortuous or serpentine maze-like path for the air stream to traverse such that the generated ozones mixes with the air and oxidizes contaminants in the air. The path may be adjusted to provide for longer or shorter periods of time for the air and ozone to mix. The air stream subsequently enters a germicidal chamber (16) and is again exposed to UV radiation at a different wavelength to destroy bacteria and any ozone in the air stream thus resulting in sterilized air. After the germicidal radiation, the sterilized air may traverse a catalytic converter (20) which removes any residual ozone residing in the sterilized air for return of the air stream to the surrounding area. A circulation fan (26) may be disposed at the top of the system to circulate the air in the surrounding area and enable the air to mix with the sterilized air.



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METHOD AND APPARATUS FOR STERILIZING AIR

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention pertains to a method and apparatus for sterilizing, deodorizing, and cleaning the air in a predetermined space. In particular, the present invention has particular use in rooms containing patients having potentially contagious diseases, areas (e.g., stationary or mobile) which have been exposed to odor emitting material, or areas requiring removal of allergens and airborne infectious agents.

2. Discussion of Prior Art

Currently, there are numerous devices known as deodorizing machines utilizing ozone and/or ultraviolet (UV) radiation to sanitize and deodorize air in a treated space (i.e., typically a room). Generally, these devices generate large amounts of ozone gas to attain the ozone concentration level necessary to facilitate deodorizing and sterilizing the air. Since ozone concentration levels required for sterilization are sufficiently high to be dangerous to people and/or animals, the use of these devices is typically limited to odors whose removal is difficult (i.e., smoke from fires, organic material spilled on clothing, etc.). Further, when the devices are used in the proximity of people and/or animals, health authorities require that ozone concentrations be reduced to safe levels. However, these reduced or "safe" levels tend to be too low to effectively deodorize and clean the air. Moreover, such devices typically use the germicidal qualities of the ultraviolet radiation to destroy bacteria in the air, but generally either expose the treated

space to high levels of radiation, thereby posing health risks to people and/or animals, such as eye trauma and skin lesions, or use very low levels of radiation requiring long exposure times.

The prior art attempts to obviate the aforementioned problems by exposing air from the treated space to the ozone and UV radiation internally of the device to thereby shield against the above-mentioned harmful effects. For example, Hirai (U.S. Patent No. 5,015,442) discloses an air sterilizing and deodorizing system wherein UV radiation generates ozone to oxidize and decompose odor-causing components in the air. The ozone is then removed by a catalyzer in conjunction with, and prior to, germicidal UV radiation where the UV radiation also removes germs and sterilizes the air. Further, Chesney (U.S. Patent No. 2,150,263) discloses a system for internally cleaning, sterilizing and conditioning air within the system. A stream of air is washed and subsequently exposed to UV radiation which generates ozone such that the combination of UV radiation and ozone destroys all bacteria in the stream. Excess ozone is removed via pumps and utilized for various purposes.

The above mentioned prior art devices suffer from several disadvantages. Since sterilization is achieved through exposure of the air to UV radiation to generate ozone which mixes with, and removes contaminants from, the air, the devices typically have a lengthy UV chamber to provide time for the ozone to interact with the air stream, thereby increasing the dimensions and cost of the device. Further, since catalytic converters are employed after the interaction of ozone with the air stream and prior to the exposure of the air stream to germicidal UV radiation, any ozone generated by or remaining after the UV radiation is unfiltered, thereby possibly leading to unhealthy concentration levels of ozone in the treated space. Moreover, the prior art devices typically utilize independent radiation sources such that the ozone generating sources may be operable when the germicidal or ozone-removing sources become inoperable, thereby leading to emissions of dangerous ozone concentrations from the device. In addition, the devices have no provision for sterilizing air intake vents which may become contaminated leading to potential growth of disease-causing bacteria on the vents.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to sterilize the air in a treated space without emitting ozone or ultraviolet radiation endangering people and/or animals.

It is another object of the present invention to reduce costs and minimize the size of an ozone chamber within an air sterilization system by utilizing an ozone chamber having a plurality of successive passages folded or wrapped over a previous passage to form a tortuous or serpentine maze-like path for the air to traverse such that ozone generated in the ozone chamber has sufficient time to interact with the air stream.

Yet another object of the present invention is to minimize the size of an air sterilization system to accommodate various environments by utilizing a substantially cylindrical housing or tube-like vertical arrangement.

Still another object of the present invention is to prevent concentration levels of ozone in an air sterilization system from reaching levels which endanger people and/or animals by removing any excess ozone residing in the sterilized air with a catalytic converter prior to returning the sterilized air to the surrounding environment.

A further object of the present invention is to sterilize, and prevent growth of disease causing material on, the air intakes of an air sterilization system by periodically causing a small amount of ozone to be directed toward the bottom of the system housing and through the air intakes.

Yet another object of the present invention is to maintain ozone concentration levels at low or "safe" levels in an air sterilization system by utilizing a single radiation source in the system to emit radiation of different wavelengths from different sections of the source to generate ozone and perform germicidal functions on the air stream, respectively. The entire single radiation source can become disabled only as a unit, thereby preventing generation of ozone when the germicidal radiation or ozone-removing section is inoperable.

The aforesaid objects are achieved individually and in combination, and it is not intended that the present invention be construed as requiring two or more of the objects to be combined unless expressly required by the claims attached hereto.

According to the present invention, a method and apparatus for sterilizing air is accomplished by a system having a substantially cylindrical housing or vertical tube-like structure. Air is drawn as a stream into the system housing at its base and flows through an ozone chamber. An ozone generating ultraviolet (UV) radiation source within the ozone chamber emits ultraviolet radiation having a wavelength of approximately 185 nanometers to irradiate the air and generate ozone which oxidizes contaminants (i.e., bacteria, virus, odor-causing element, etc.) residing in the air stream. The ozone chamber includes the ozone generating UV source surrounded by several eccentric (i.e., eccentrically disposed) or concentric cylindrical tubes forming airflow passages in the spaces between the tubes. The passages form a tortuous or serpentine maze-like path for the air to traverse while maintaining the air stream within the ozone chamber for a residence time sufficient for the ozone to interact with the air. The cross-sectional area of the flow path, and hence the volume, steadily increases after exposure to the UV radiation to reduce air velocity and increase the air stream residence time in the chamber. Subsequent to traversing the ozone chamber path, the air stream enters the germicidal chamber disposed above the ozone chamber and containing one or more germicidal UV radiation sources. The germicidal UV radiation sources irradiate the air stream and destroy bacteria and break down ozone residing therein. The germicidal chamber may include highly polished or etched aluminum disposed on the chamber walls to reflect and increase the intensity of the germicidal radiation. The increased intensity inactivates a greater number of organisms and removes a greater amount of ozone from the air stream. The germicidal UV radiation sources generate radiation having a wavelength of approximately 254 nanometers to destroy bacteria, viruses, mold spores and ozone remaining after the interaction of air and ozone in the ozone chamber. The resulting sterilized air from the germicidal chamber may pass through a catalytic converter disposed above the germicidal chamber to remove any remaining ozone by either converting the ozone back to oxygen, or filtering the ozone from the air stream. An internal fan disposed above the catalytic converter or germicidal chamber (if the catalytic converter is not present) draws the air into the system from the base and through the chambers. An external air circulation fan may be disposed at the top of the system to enable the air in the

surrounding area to mix with the sterilized air, thereby increasing the rate of sterilization of the area. In addition, a small fan may be disposed adjacent the ozone chamber and above the base where air is drawn into the system to facilitate periodic sterilization of the air entrance at the base of the system. An automatic timing arrangement periodically removes power from the internal fan and radiation sources and applies power to the small fan to allow a small amount of ozone to be directed from the ozone chamber toward the base to sterilize, and prevent the growth of disease causing material on, the air entrance.

The radiation sources may include a single combination UV radiation emitting bulb with different sections of the bulb emitting radiation of different respective wavelengths. The different sections of the bulb are disposed in the corresponding ozone and germicidal chambers. Where the germicidal chamber is designed to include a pair of radiation sources, the additional source, other than the germicidal section of the combination bulb, may be an independent bulb emitting radiation at the above-mentioned wavelength of approximately 254 nanometers. Alternatively, the radiation sources may all be implemented by separate independent bulbs emitting radiation having wavelengths of approximately 185 or 254 nanometers depending upon the chamber in which the bulb is disposed. The bulbs may be powered by a conventional AC ballast (for use in stationary areas), or a conventional DC ballast connected to a battery to enable the system to be portable and used in mobile environments (e.g., cars, boats, trucks, trailers, etc.).

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of a specific embodiment thereof, particularly when taken in conjunction with the accompanying drawings wherein like reference numerals in the various figures are utilized to designate like components.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is a view in elevation and partial section of an air sterilization system according to one embodiment of the present invention.

Fig. 1b is a diagrammatic view in transverse section of the ozone chamber employed in the embodiment of Fig. 1a.

Fig. 2a is a view in elevation and partial section of an alternative embodiment of the air sterilization system of the present invention.

Fig. 2b is a diagrammatic view in transverse section of the ozone chamber employed in the embodiment of Fig. 2a.

Fig. 3a is a view in elevation and partial section of an alternative configuration for the ozone chamber of Fig. 2a.

Fig. 3b is a partially diagrammatic view in transverse section of the ozone chamber of Fig. 3a.

Fig. 4 is an electrical schematic diagram for an air sterilization system according to the present invention.

Fig. 5 is an electrical schematic diagram for an air sterilization system having an external air circulating fan according to the present invention.

Fig. 6 is a procedural flowchart illustrating facilitation of the periodic sterilization of the intake vents according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A system 2 for sterilizing, deodorizing, and cleaning the air within the confines of a predetermined area is illustrated in Figs. 1a, 1b. Specifically, system 2 includes a base platform 3, and a substantially hollow cylindrical housing 5. In the illustrated embodiment, base platform 3 has a substantially square transverse (i.e., horizontal) cross-section having a length and width of approximately one foot, and is approximately two inches high. Housing 5 extends vertically from the approximate center of base platform 3 and has a diameter of approximately nine inches with a height of approximately four feet. Base platform 3 supports housing 5 such that the housing stands erect in a substantially vertical position. The exemplary dimensions described herein are typical in relation to systems for relatively stationary treated spaces (e.g., a room), however, the principles of the present invention are equally applicable to systems for mobile treated spaces (e.g., cars, trailers, boats, trucks, etc.). Further, the shape and dimensions of the system may be varied to accommodate various areas and

applications. For example, the system dimensions for mobile areas, such as the interior of vehicles, are much smaller than the dimensions described herein and are dependent upon the particular area and placement of the system. Also, although the preferred orientation of housing 5 is vertical as shown, other orientations are certainly possible without departing from the principles of the invention.

The various components of the sterilization system are disposed within housing 5 and include a ballast 4, ozone generation and soaking chamber 8, germicidal chamber 16 and internal fan 22. Ballast 4 is a conventional ballast for supplying appropriate current to ultra-violet (UV) radiation emitting sources 36, 62 described below and is disposed at the bottom of housing 5 adjacent base platform 3. The ballast is enabled by a power switch 18 mounted on an exterior surface of housing 5 coincident germicidal chamber 16. A power light 38 is disposed below and adjacent power switch 18 to indicate when power has been enabled to the system. Intake vent 6 is defined through the housing wall and extends along the entire housing circumference 5 above and adjacent ballast 4. Intake vent 6 includes a plurality of louvers or covered slots 25 angled outwardly down toward the base of the system and disposed in a stack-like manner (i.e., one above the other) to permit contaminated air from the surrounding environment to enter the housing. A ballast divider 7, typically a substantially circular plate or disk having dimensions slightly smaller than the cross-section of housing 5, isolates ballast 4 from the incoming air and directs the air into ozone chamber 8.

Ozone chamber 8 is disposed above and adjacent intake vent 6 and extends upwardly for approximately nine inches from the vent. The ozone chamber includes an ozone generation section 12 of the ultra-violet (UV) radiation source 36, and a plurality of eccentric tubes 55, 56 surrounding ozone section 12 of the bulb and joined tangentially at a common point along their circumferences. The tubes form longitudinally reversing sections of a tortuous or serpentine maze-like flow path (indicated by arrows in Fig. 1a) for the air stream to traverse. The flow path includes a cylindrical ozone generating region 72 defined by the area or passage 50 encompassed by the innermost tube 55 nearest ozone section 12, and a soaking or disbursing region 74 defined by the meniscal cross-sectional areas of passages 51, 52 between the immediately successive tubes 55, 56 and housing 5. Radiation source 36

is typically a substantially cylindrical UV radiation emitting bulb and may be implemented by a single bulb having an ozone section 12 and germicidal section 14 emitting radiation at different wavelengths (i.e., 185 and 254 nanometers) from the ozone and germicidal sections, respectively. Alternatively, radiation source 36 may be implemented by two independent substantially cylindrical bulbs corresponding to ozone section 12 and germicidal section 14, wherein the independent bulbs are disposed one on top of the other in the respective ozone and germicidal chambers and emit radiation at the wavelength required in the particular chamber (i.e., 185 nanometers in the ozone chamber, and 254 nanometers in the germicidal chamber). Upper and lower ozone dividers 9, 17 define the top and bottom boundaries of ozone chamber 8 and isolate that chamber from germicidal chamber 16 and intake vent 6, respectively. Lower ozone divider 17 is disposed above and adjacent intake vent 6 and includes an air entranceway 27 adjacent the interior surface of housing 5 and coincident with ozone generating region 72. A small ozone fan 70, typically a conventional fan or blower device, may be mounted near or on the lower ozone divider 17 coincident entranceway 27 via a bracket (not shown) to draw ozone out of the ozone chamber and through intake vent 6 to sterilize the vent as described below. Radiation source 36 is disposed adjacent an interior surface of housing 5 adjacent power switch 18 and extends from ozone chamber 8 through upper ozone divider 9 into germicidal chamber 16. Bulb section 12 extends down from upper ozone divider 9 for approximately one-half the longitudinal length of ozone chamber 8.

Eccentric tubes 55, 56 surround bulb section 12 such that the bulb section resides at the approximate center of innermost tube 55, and each succeeding tube has a larger diameter than the previous tube. Each eccentric tube 55, 56 is preferably a right circular cylinder with a portion of its exterior surface in mutual tangential contact with the other tubes adjacent the interior surface of housing 5. Successive tubes have successively increasing radii, and their longitudinal axes are parallel but laterally spaced. The resulting transverse cross-section appears as a circle surrounded by successive meniscuses. The minimum difference in diameter of successive tubes 55, 56 is substantially equal to the cross-sectional diameter of radiation source or bulb 36. In practice, however, it is preferred that these diametric differences be considerably

greater than that. By way of example only, tubes 55, 56 in a preferred embodiment have diameters of three and five inches, respectively, with housing 5 having a diameter of eight inches. Lower ozone divider 17 is a substantially circular plate or disk having a cut-away circular portion, corresponding to the diameter of innermost tube 55, defining air entranceway 27. Similarly, upper ozone divider 9 is a substantially circular plate or disk covering the upper end of outermost tube 56 such that the upper portion of outermost passage 52 of meniscal cross-section remains unobstructed to permit air and ozone to exit ozone chamber 8 and enter germicidal chamber 16. Alternatively, the upper and lower ozone dividers 9,17 may be substantially circular plates or disks having dimensions slightly smaller than the cross-section of housing 5 with holes or openings defined in the plate coincident areas 50, 52 to allow air to enter and exit ozone chamber 8, respectively.

The longitudinal or axial length of each eccentric tube 55, 56 is slightly less than the axial length of ozone chamber 8 such that tube 55 extends from divider 17 to just short of divider 9, and tube 56 extends from divider 9 to just short of divider 17. This alternating longitudinal offset arrangement of tubes 55, 56 allows the air to flow transversely from one longitudinal passage 50, 51, 52 to the next, thereby forming the overall path through which air traverses ozone chamber 8. Passages 50, 51, 52 are parallel to the longitudinal axis of ozone chamber 8 with passage 50 defined by the area encompassed by innermost tube 55 and passages 51, 52 defined in the space between an exterior surface of a preceding tube and an interior surface of a succeeding tube (or housing 5 in the case of passage 52). Passages 50, 51, 52, in effect, fold or wrap longitudinally back over a preceding passage such that the path has a tortuous or serpentine maze-like pattern for the air to follow. Since the lengths of tubes 55, 56 are less than the length of ozone chamber 8, passages 50, 51 include respective spaces providing flow communication between successive passages at one end of each tube proximate either upper or lower ozone divider 9, 17. These spaces are alternately disposed adjacent opposite dividers 9, 17 to enable the air to switch the flow direction and traverse ozone chamber 8 in a longitudinally reciprocating manner through succeeding passages 50, 51, 52. In other words, the air in passages 50, 51, 52 alternately flows toward the upper and lower ozone dividers 9, 17 such that for each

succeeding passage the air is flowing in an opposite longitudinal direction (i.e., the air flows toward upper ozone divider 9 in cylindrical passage 50, toward lower ozone divider 17 in meniscal passage 51, and toward upper ozone divider 9 in meniscal passage 52).

Lower ozone divider 17 guides the air from intake vent 6 to entrance 27 to ozone chamber 8 such that the air traverses the path through passages 50, 51 and 52 of increasing cross-sectional area. The final section is defined adjacent the interior surface of housing 5. When the air enters ozone chamber 8, it initially traverses ozone generating region 72 defined by the passage 50 having a circular cross-section and formed by the innermost tube 55. This innermost passage surrounds ozone section 12 which irradiates the surrounding air with UV radiation having a wavelength of approximately 185 nanometers to generate ozone. The relatively small cross-section of ozone generating region 72 permits the flowing air to come into close contact with the ozone section 12 of the bulb, thereby subjecting the air to highly intense radiation (i.e., a good sterilient) since the radiation intensity is proportional to the square of the distance from the radiation source. Subsequent to ozone generating region 72, the air traverses soaking region 74 defined by successive passages 51, 52 of increasing meniscal or crescent-shaped cross-section. The cross-sectional area of the air flow path from ozone generating region 72 through soaking region 74 thus steadily increases. The increasing cross-sectional area results in a decreasing air velocity through passages 51, 52, causing the generated ozone to be distributed throughout the flowing air stream. Further, the tortuous or serpentine maze-like pattern also churns the air flow, making it turbulent and enhancing ozone distribution. The reduced air velocity provides sufficient time for the ozone to mix with the air and oxidize and/or remove contaminants (i.e., bacteria, virus, odor-causing element, etc.) from the air. After traversing outermost passage 52, the air stream enters germicidal chamber 16 through the entrance formed by upper ozone divider 9 and passage 52. The resident time of air in the ozone chamber and the air velocity may be determined by the diameters of eccentric tubes 55, 56 and/or the number of tubes (which increases or decreases the number of passage sections), and the internal fan speed. Thus, the ozone chamber may be configured to accommodate various requirements and

applications by varying the diameter and number of tubes and/or the internal fan speed to adjust the residence time and air velocity.

Germicidal chamber 16 is disposed above ozone chamber 8 and extends above upper ozone divider 9 approximately nine inches in the preferred embodiment. Germicidal chamber 16 contains the germicidal radiation section 14 of radiation source 36, and a second independent radiation source 62, typically a substantially cylindrical UV radiation emitting bulb, with each source emitting UV radiation having a wavelength of approximately 254 nanometers. Germicidal radiation section 14 of the main bulb extends axially through upper ozone divider 9 from section 12 for substantially the full length of germicidal chamber 16 at a location radially displaced from the central longitudinal axis of housing 5. Radiation source 62 is also radially displaced from the axis of housing 5 at a location angularly displaced approximately one-hundred eighty degrees from germicidal section 14. The interior surface of housing 5 surrounding germicidal chamber 16 includes a layer of highly polished or etched aluminum to reflect and increase the intensity of the radiation emitted by germicidal section 14 and radiation source 62. The increased intensity deactivates and destroys a greater number of organisms and removes a greater amount of ozone from the air stream than occurs without the reflective surface. Radiation sources 36, 62 are supported by a rod 19 disposed toward the top of germicidal chamber 16 and extending diametrically across the interior of housing 5. Supports 21, typically substantially annular and made of rubber, plastic or other sturdy material capable of securing the radiation sources, are disposed at respective locations on rod 19 to secure radiation sources 36, 62 to the rod. Further, a support 21 is disposed on a top surface of upper ozone divider 9 to secure radiation source 36 to the divider. Another support 21 is similarly situated on a rod or flange 31 disposed toward the bottom of germicidal chamber 16 and extending from the interior surface of housing 5 to secure the bottom of source 62 in place. Alternatively, radiation sources 36, 62 may be secured by brackets, substantially circular plates or disks having dimensions slightly smaller than the cross-section of housing 5 with holes or openings for receiving the radiation sources and allowing air to flow, or other securing mechanisms extending from the interior surfaces of housing 5. The air stream flows into germicidal chamber 16 from ozone chamber 8 where the

radiation emitted by germicidal radiation section 14 and radiation source 62 destroys bacteria, molds, spores, and ozone residing in the air stream.

A catalytic converter 20 may be disposed above and adjacent germicidal chamber 16 to remove any remaining ozone in the air stream by either converting the ozone to oxygen, or filtering the ozone from the air stream. Catalytic converter 20 is typically used in cases where the germicidal radiation does not sufficiently remove excess ozone from the air stream. The catalytic converter 20 is a substantially circular plate or disk disposed perpendicular to the longitudinal axis of housing 5 and having dimensions slightly less than the cross-section of the housing. The converter is made of a conventional catalytic converting material which may include activated charcoal (i.e., for filtering the ozone), molybdenum disulfide (i.e., for converting the ozone to oxygen) or other device or material for removing excess ozone. Internal fan 22 is disposed above and adjacent catalytic converter 20 or germicidal chamber 16 (if catalytic converter 20 is not present) for drawing air through the sterilization system and directing sterilized air back into the surrounding environment through exhaust vent 24. Exhaust vent 24 is disposed above internal fan 22 and is substantially similar to intake vent 6 described above except that its louvers or covered slots 32 are angled upwardly and outward. Internal fan 22 is a conventional fan or blower and, in the preferred embodiment, operates at a speed of 2,950 r.p.m. Fan 22 is suspended from a rod 23 disposed above catalytic converter 20 or germicidal chamber 16 (if catalytic converter 20 is not present) and extending diametrically across housing 5. Alternatively, internal fan 22 may be supported by a substantially circular plate or disk circumferentially contoured to match the interior of housing 5 with holes or openings defined in the plate to permit air flow therethrough. An external circulation fan 26 may be disposed above and adjacent exhaust vent 24 for circulating air in the surrounding space. External circulation fan 26 is disposed externally of housing 5 and functions to mix air from the surrounding ambient environment with the sterilized air blown upward from exhaust vent 24. A fan power switch 42 is mounted on the exterior surface of housing 5 above and adjacent power switch 18 to actuate external circulation fan 26 independently of power switch 18. Fan power light 40 is disposed above and adjacent fan power switch 42 to indicate that power has been applied to external circulation fan 26. A fan divider

wall 29 is disposed adjacent and above exhaust vent 24 to isolate external circulation fan 26 from chamber 16 and guide the sterilized air out the exhaust vent. External circulation fan 26 may be any conventional fan or blower device and circulates the air in the external space such that the air mixes with the sterilized air from exhaust vent 24, thereby increasing the rate of air sterilization in that space.

As the system sterilizes air, contaminated air enters through intake vent 6 where there is a potential for contaminants to cling to the vents and cultivate. In order to prevent this cultivation, the system automatically and periodically sterilizes the intake vent 6 to neutralize the contaminants as illustrated in Figs. 1a, 1b, 4 - 6. Specifically, a microprocessor 68 is powered by a conventional power supply 78 and monitors when a time interval between sterilizations has elapsed. The time interval is predetermined and typically set such that the intake vent 6 may be sterilized either once a day, or once a week depending upon the length of time the system is in use. Microprocessor 68 is booted in a conventional manner when power is applied to the system and initializes the time setting to the desired sterilization time interval and then iteratively decrements the time until time has expired (i.e., the time is equal to zero). Alternatively, microprocessor 68 may initialize the time to zero and iteratively increment the time and compare the incremented time value to the predetermined time period. The decremented or incremented time value may be stored in a non-volatile memory (not shown) such that microprocessor 68 maintains the time when the system is enabled after a power shut down (i.e., the system has been turned off). Once microprocessor 68 determines that the time interval has expired, the microprocessor manipulates switch 60 (normally closed) to an open position to remove power from the remaining parts of the system (i.e., the internal fan 22, ballast 4 and radiation sources 36, 62). Ozone fan 70, disposed above and adjacent intake vent 6 at the entrance 27 to ozone chamber 8, is typically activated for approximately five seconds subsequent to powering the system down by microprocessor 68. Ozone fan 70 draws any ozone residing in the ozone chamber out of the chamber and through the intake vent 6 to sterilize the vent and neutralize the contaminants in substantially the same manner described above for the ozone removing contaminants from the air. Subsequent to sterilizing intake vent 6, microprocessor 68 disables ozone fan 70 and manipulates switch 60 to a closed

position to enable power to the system. Microprocessor 68 may be programmed to sterilize intake vent 6 at any desired time interval or enable ozone fan 70 for any duration of time to accommodate the sterilization of the intake vent. The microprocessor and power supply 78 may be any conventional or commercially available microprocessor and power supply or other circuitry capable of supplying power and determining the expiration of a time period, respectively. Further, it is to be understood that one of ordinary skill in the art could transform the algorithms described above and in the flow chart of Fig. 6 into software in any of a number of computer languages to program the microprocessor to function as described above.

Radiation source 36 in the preferred embodiment includes a substantially cylindrical combination UV radiation emitting bulb which simultaneously emits radiation at the desired wavelengths (i.e., 185 and 254 nanometers) from different sections of the bulb. Such a combination bulb may be constructed by utilizing a conventional UV radiation emitting bulb exciting a gas to produce ultraviolet rays over a broad portion of the UV frequency spectrum, and coating the exterior surface of the bulb with a compound to filter and pass only the particular frequency bands of interest. For further discussion of the above-mentioned coating technique, reference is made to U.S. Patent Nos. 2,362,384 and 2,362,385 (Libby) the disclosures of which are expressly incorporated herein by this reference. Alternatively, the combination bulb may be implemented by a conventional UV radiation emitting bulb exciting a gas to produce ultraviolet rays wherein a dopant is disposed in the glass at different sections of the bulb to filter and pass specific desired bands of ultraviolet energy. Reference is made to U.S. Patent No. 3,374,381 (Albinak et al), the disclosure of which is expressly incorporated herein by this reference, for further discussion of the above-mentioned doping process. Radiation source 36 typically includes two sections having the appropriate dopant or coating to produce UV radiation having wavelengths of approximately 185 and 254 nanometers. The coated or doped sections are disposed in the ozone and germicidal chambers to supply the proper radiation for creating ozone from the air and performing germicidal functions, respectively. Alternatively, radiation source 36 may be implemented by two independent substantially cylindrical UV radiation emitting bulbs disposed in the respective ozone and germicidal chambers.

Each bulb may be a commercially available UV radiation emitting bulb and emit radiation having a wavelength of either 185 or 254 nanometers depending upon the particular chamber where the bulb is to be disposed. However, the combination bulb provides an inherent safety feature which prevents ozone from being generated when the germicidal radiation is not being produced. Since germicidal radiation destroys ozone in the air stream, the absence of such radiation may result in dangerous concentrations of ozone being emitted by the system. The combination bulb includes the inherent feature of disabling both bulb functions when the portion of radiation source 36 disposed in the germicidal chamber is inoperative, thereby automatically preventing the generation of ozone without having the germicidal radiation to remove the ozone. The use of two independent bulbs typically requires an ozone detector to accomplish this same feature as described below.

An alternative embodiment of the system utilizing only a single radiation source in the germicidal chamber is illustrated in Figs. 2a, 2b. Specifically, system 2 is substantially similar to the system described above except that radiation source 36 is disposed at the approximate center of the ozone and germicidal chambers 8, 16, respectively. Radiation source 36 may be implemented by either the combination bulb, or two independent bulbs corresponding to ozone section 12 and germicidal section 14 described above.

Ozone chamber 8 includes ozone section 12 of radiation source 36 disposed at the approximate center of the chamber surrounded by a plurality of concentric right cylindrical tubes 55, 56 coaxially disposed about ozone section 12. Concentric tubes 55, 56 form a tortuous or serpentine maze-like path (indicated by arrows in Fig. 2a) in a substantially similar manner to that described above for the eccentric tubes. Each radially outward successive tube 55, 56 is slightly greater in diameter than a previous tube to form cylindrical passage 50 in the area encompassed by innermost tube 55 and passages 51, 52 of annular cross-section in the spaces between the tubes for the air to flow. The difference in successive diameters is at least equal to the cross-sectional diameter of radiation source 36. Upper and lower ozone dividers 9, 17 define the top and bottom boundaries of ozone chamber 8. Upper ozone divider 9 is a substantially annular plate or disk having dimensions slightly less than the cross-section of housing

5. Portions of upper ozone divider 9 at the outermost passage 52 include openings or slots 90 to permit the air stream to enter germicidal chamber 16. Alternatively, upper ozone divider 9 may be a substantially circular plate or disk having dimensions substantially similar to the cross-section of outermost tube 56 to permit air to flow from passage 52 to germicidal chamber 16. Radiation source or bulb 36 extends through the approximate center of upper ozone divider 9 and has an ozone section 12 extending down approximately half the longitudinal length of ozone chamber 8. Lower ozone divider 17 is a substantially circular plate or disk having a cut-away central portion, corresponding to the cross-section of the innermost tube 55 nearest ozone section 12, defining an entrance 27 into ozone chamber 8. Alternatively, lower ozone divider 17 may be a substantially circular plate or disk having dimensions slightly less than the cross-section of housing 5 with holes or openings defined in the plate at passage 50 to allow air to enter the ozone chamber. Ozone fan 70 is mounted on the bottom surface of divider 17 at entrance 27 via a bracket (not shown) to draw ozone out of chamber 8 and sterilize intake vent 6 as described above.

The length of each tube 55, 56 is slightly less than the length of ozone chamber 8 such that tube 55 extends from the lower divider 17 to just short of upper divider 9, and tube 56 extends from upper divider 9 to just short of lower divider 17. The terminations of the tubes just prior to reaching the divider permit flow between the different sections of the flow path. Specifically, the spaces linking successive passages 50 ,51, 52 and defined between the upper or lower ozone dividers 9, 17 and the ends of the tubes 55, 56 permit the air to flow through succeeding passages 50, 51, 52 [illegible]n passage 50 defined by the area encompassed by innermost tube 55 and passages 51, 52 defined in the space between the interior surface of a succeeding tube (or housing 5 in the case of passage 52) and the interior surface of a preceding tube. The passages 50, 51, 52 form a tortuous or serpentine maze-like path for the air to follow. The air flows through the successive radially outward passages in all directions from ozone section 12 toward the interior surfaces of housing 5, and enters germicidal chamber 16 through the openings 90 defined in upper ozone divider 9.

Air is drawn into the system through intake vent 6 via internal fan 22 as described above. The air is guided by ballast and lower ozone dividers 7, 17 into

ozone chamber 8 via entrance 27 in lower ozone divider 17. The air enters an ozone generating region 72, defined by and interiorly of innermost tube 55, where the air comes in close contact with ozone section 12 of the bulb. Ozone section 12 emits radiation having a wavelength of approximately 185 nanometers to irradiate the air and to generate ozone as described above. The air then traverses successive passages 51, 52 of increasing annular cross-section forming a soaking region 74. The cross-sectional area of the flow path from ozone generating region 72 through soaking region 74 thus steadily increases. The increasing cross-sectional area results in a decreasing air velocity through passages 51, 52, causing the generated ozone to be distributed throughout the flowing air stream. The reduced air velocity and maze-like pattern of the flow path distribute the ozone throughout the air stream and provide time for the ozone to oxidize and/or remove contaminants as described above. The air stream traverses each successive passage 50, 51, 52 of the flow path in alternating longitudinal direction as described above, and after traversing outermost passage 52, enters germicidal chamber 16 through openings 90 defined in upper ozone divider 9.

Germicidal chamber 16 is substantially similar to the germicidal chamber described above except that germicidal section 14 of radiation source or bulb 36 is disposed at the approximate center of the chamber and is the sole source of germicidal radiation. Germicidal section 14 extends from ozone section 12 through upper ozone divider 9 for substantially the entire length of germicidal chamber 16. An upper germicidal divider 11 is situated at the top of germicidal chamber 16 and below the catalytic converter 20 or internal fan 22 (if the catalytic converter is not present). Upper germicidal divider 11 is a substantially annular plate with a circumference matching the interior surface of housing 5 and with openings or slots 92 defined therein to allow air to flow out of germicidal chamber 16. A pair of rings or stoppers 80 are annularly disposed about germicidal section 14 proximate upper ozone and upper germicidal dividers 9, 11, respectively. The lower stopper 80 prevents germicidal section 14 of the bulb from slipping into ozone chamber 8 by abutting upper ozone divider 9 when the germicidal section begins to slide. The upper stopper 80 similarly prevents the bulb from sliding upward by abutting divider 11. Stoppers 80 have a diameter greater than the diameter of the openings defined in annular dividers 9 and 11 and can maintain

germicidal section 14 above the upper ozone divider in case radiation source 36 becomes unsecured or loose. The air and ozone mixture enters germicidal chamber 16 from ozone chamber 8 and is exposed to radiation from germicidal section 14 of the bulb having a wavelength of approximately 254 nanometers to destroy contaminants and decompose any ozone in the air stream. The air exits germicidal chamber 16 through openings 92 in upper germicidal divider 11 to traverse catalytic converter 20 (if present) or be directed back to the surrounding area via exhaust vent 24 in substantially the same manner described above.

An alternative embodiment for ozone chamber 8 is illustrated in Figs. 3a-3b. Ozone chamber 8 is substantially similar to the ozone chamber described above for Figs. 2a, 2b, however, it is to be understood that the principles of this embodiment are equally applicable to the ozone chamber of Figs. 1a, 1b. Specifically, a plurality of concentric tubes 55, 56 surround ozone section 12 of radiation source 36 to form a tortuous or serpentine maze-like path (indicated by the arrows in Fig. 3a) for the air to follow in substantially the same manner described above. The longitudinal length of each tube 55, 56 is substantially similar to the longitudinal length of ozone chamber 8 such that the tubes fully extend from lower ozone divider 17 to upper ozone divider 9. In order to permit the air to flow in successive passages 50, 51, 52 with passage 50 defined by the area encompassed by innermost tube 55 and passages 51, 52 formed between the interior surface of a successive tube (or housing 5 in the case of passage 52) and the exterior surface of a preceding tube, the tubes 55, 56 include a plurality of openings or slots 28 disposed about the circumference of the tubes and alternately located toward the upper and lower ozone dividers 9, 17. The slots 28 link successive passages 50, 51, 52 and direct the air to traverse the successive passages of the flow path in opposite longitudinal directions to mix the ozone with the air as described above. Further, a plurality of vortex generators 15 are disposed in passage 50 toward upper ozone divider 9 between tubes 55, 56. Vortex generators 15 enhance the churning of the air to assist the ozone in mixing with the air to oxidize the contaminants. The openings or slots 28 may be any size or shape allowing air to flow. The air enters ozone chamber 8 through entrance 27 defined in lower ozone divider 17 and traverses the flow path through ozone generating region 72 (defined by passage 50) and soaking

region 74 (defined by passages 51, 52) to respectively generate ozone and mix the ozone with the air stream as described above. The increasing cross-sectional area of the flow path in soaking region 74 reduces air velocity to provide time for the ozone to mix with the air and remove contaminants. The air traverses successive passages 50, 51, 52 through holes 28 in alternating longitudinal directions while being churned via vortex generators 15 and the maze-like pattern of the successive passages until reaching passage 52 where the air exits the ozone chamber through openings 90 defined in upper ozone divider 9.

The electrical circuitry for the system is illustrated in Fig. 4. Supply voltage is connected across leads 64, 66 from a conventional wall outlet jack, or from a portable 12V DC source (e.g., a battery) when using a DC ballast to enable the system to be portable and used in mobile areas. Power switch 18 is disposed on lead 64 to enable the driving voltage to power the circuit when the power switch is closed (i.e., the system is turned on). Power light 38 is connected between leads 64, 66 and is illuminated in response to power switch 18 being closed to indicate that power has been applied to the system. Similarly, internal fan 22 is connected between leads 64, 66 and is actuated by closure of switch 18. Ballast 4 is connected between leads 64, 66 and to radiation sources 36 (i.e., the combination bulb or two independent bulbs) and 62 (when used in the preferred embodiment). Ballast 4 supplies current to the radiation sources 36, 62 upon closure of switch 18 to generate the UV radiation needed to produce ozone and perform germicidal functions as described above. Alternatively, ballast 4 may be a DC ballast which may be powered by an approximate 12V DC source (e.g., battery or other source) thereby rendering the system portable for use in automobiles or other mobile areas (e.g., interiors of other vehicles, trailers, etc.) Microprocessor 68 and power supply 78 are connected between leads 64, 66 in series with ozone fan 70, and are enabled by the closure of power switch 18. Microprocessor 68 controls a switch 60 (normally closed) disposed on lead 64 subsequent to power switch 18 and power light 38 to remove power from the system (i.e., internal fan 22, ballast 4 and radiation sources 36, 62), and enables ozone fan 70 to draw ozone from chamber 8 and through intake vent 6 to sterilize the intake vent as described above.

The circuitry of Fig. 5 is substantially similar to the circuitry described above for Fig. 4 except for the inclusion of external circulation fan 26 and corresponding fan power switch 42, and fan power light 40. Power light 38, power switch 18, ballast 4, microprocessor 68, power supply 78, ozone fan 70 and switch 60 are connected as described above. Fan power light 40 is connected between leads 64, 66 in series with power switch 42 and is illuminated in response to fan power switch 42 being closed (i.e., external circulation fan 26 being turned on). Similarly, external circulation fan 26 is connected between leads 64, 66 in parallel with light 40, and is also actuated by fan power switch 42. Power switches 18, 42 are each connected in the circuit to have access to the driving voltage on lead 64 independently of each other such that external circulation fan 26 and the rest of the system may be operated independently.

Operation of the system is now described with reference to Figs. 1a, 1b, 2a, 2b, 3a, 3b, 4-6. Specifically, power switch 18 is turned on to illuminate power indicator light 38, and actuate internal fan 22, ballast 4, and microprocessor 68. Fan power switch 42 may also be turned on to actuate external circulation fan 26 and illuminate fan power light 40. Ballast 4 supplies the appropriate current to radiation source 62 (i.e., an independent radiation emitting bulb), and radiation source 36 (i.e., either a two-band radiation emitting bulb or two independent single band radiation emitting bulbs as described above) depending upon the system configuration for generating the ozone and germicidal radiation. Internal fan 22 draws air from the surrounding area through intake vent 6 and into ozone chamber 8. Ozone section 12 of radiation source 36 irradiates the air in ozone generating region 72 of the flow path to produce ozone from oxygen, which ozone mixes with and oxidizes the contaminants in the air. The air stream traverses the tortuous or serpentine maze-like flow path within ozone chamber 8 while enabling the ozone to mix with the air stream and oxidize the contaminants in soaking region 74 as described above for the various ozone chamber embodiments. Subsequent to traversing outermost passage 52 in ozone chamber 8, the air stream enters germicidal chamber 16 where the air stream is irradiated by radiation source 62 and/or germicidal section 14 of radiation source 36 to remove bacteria and ozone from the air stream. After exposure to the germicidal radiation, the air stream may pass through a catalytic converter 20 which removes any residual ozone in the air stream by

either converting the ozone to oxygen, or filtering the ozone from the air stream. The sterilized air stream is then directed back into the surrounding area through exhaust vent 24 via internal fan 22. External circulation fan 26 circulates the air in the surrounding area to mix with the sterilized air emitted through exhaust vent 24 to sterilize the surrounding area at an increased rate. Microprocessor 68 periodically powers down the system (i.e., internal fan 22 and ballast 4) and enables ozone fan 70 to sterilize intake vent 6 as described above.

It will be appreciated that the embodiments described above and illustrated in the drawings represent only a few of the many ways of implementing the principles of the invention in an air sterilization system.

The chambers, passages, tubes, housing and base may be constructed of PVC plastic or other suitably sturdy material. The ballast may be any conventional or commercially available AC or DC ballast or other circuitry to supply appropriate currents to the radiation sources. The microprocessor may be any conventional or commercially available microprocessor, combinational logic or other circuitry capable of maintaining time and activating a fan. The power supply may be any conventional or commercially available power supply or circuitry capable of supplying appropriate power to the microprocessor or timing circuitry. The radiation sources may be any conventional or commercially available UV bulbs or other devices capable of generating the radiation having the proper wavelengths. Further, the radiation sources may be implemented by any single device capable of producing the radiation having the desired varying wavelengths. The germicidal chamber may be lined with aluminum or other reflective material capable of reflecting the radiation. The fans may be conventional or commercially available fans or other devices capable of directing air flow. The intake and exhaust vents may be any type of opening capable of permitting air to enter and exit the system. The switches and lights or indicators may be conventional switches and indicators or other devices capable of connecting a circuit or indicating the occurrence of a condition. The components of the system may be disposed within, and on, the system in any number of variations capable of producing the sterilized air.

Although the embodiments have been described and illustrated herein with the system housing having its longitudinal axis oriented vertically, it will be understood that horizontal orientation, and orientations between horizontal and vertical, are permissible and within the scope of the invention.

The dimensions and shape of the system may be modified to accommodate varying spatial requirements and applications. Further, the ozone chamber may be implemented by any structures or devices forming any tortuous path where inlet air is irradiated upon entry into the ozone generating region and then slowed to some extent to soak with the generated ozone while traversing an expanding flow path. For example, the system may include a substantially rectangular housing with a tortuous or serpentine path formed by a series of substantially rectangular plates separated by a predetermined distance to control air flow and velocity and enable the generated ozone to mix with the air.

It is apparent that the system may be enhanced by incorporating several features into the system. Specifically, a sliding mechanism, such as a shield or sleeve, may be disposed around the radiation source (i.e., ozone section 12) disposed in the ozone chamber. The shield is either manually or automatically slidable, via a solenoid, along a longitudinal axis of the system to control the amount of radiation emitted and hence the amount of ozone generated. A flashing light may be disposed on the top of the system as a warning indicator when the sliding mechanism is set to generate high levels of ozone. If the light should fail, the system would cease and become inoperable. The shield may also cover the entire portion of the ozone radiation source such that the system may utilize only the germicidal radiation to sterilize the air and remove ozone in the system and surrounding area. Further, timing mechanisms may be incorporated into the system to sterilize the air at preset times (i.e., at night when no one is in the area and high concentrations of ozone may be used). The timing mechanisms may also be utilized to maintain the age of the UV bulbs and indicate the times when the bulbs should be replaced (e.g., indicate replacement every 9,000-15,000 hours). Moreover, an ozone detector may be disposed as an added precaution when high concentrations of ozone are being produced, especially for embodiments utilizing separate bulbs in the ozone and germicidal radiation chambers. The detector

would disable the system in response to detecting ozone concentrations in excess of 0.05 parts per million.

From the foregoing description it will be appreciated that the invention makes available a novel air sterilization system wherein air is exposed to UV radiation at a first wavelength to generate ozone which oxidizes contaminants in the air while traversing a space-saving tortuous or serpentine maze-like path. The long tortuous path having an increasing flow cross-section enhances ozone distribution in the contaminated air and does so within a relatively small volume or housing. Subsequently, the air is exposed to UV radiation at a second wavelength to destroy bacteria and ozone in the air. The air may then traverse a catalytic converter to remove any residual ozone residing in the air, and be returned back to the surrounding environment

Having described preferred embodiments of a new and improved air sterilization system, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. it is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims.

What is Claimed is:

1. An air sterilization system for receiving contaminated air from a surrounding environment, sterilizing the contaminated air, and recirculating the sterilized air back to the surrounding environment comprising:

intake means for receiving said contaminated air from said surrounding environment;

an ozone chamber including an ozone radiation source for irradiating said contaminated air to generate ozone to remove contaminants residing in the contaminated air, wherein said ozone chamber further includes a tortuous or serpentine path through which the air passes after being irradiated, the path serving to decrease air flow velocity and enhance distribution of ozone in the flowing air;

a germicidal chamber including at least one germicidal radiation source for irradiating the air and ozone mixture to remove residual contaminants and ozone from the mixture resulting in sterilized air;

exhaust means for returning the sterilized air back to the surrounding environment; and

blower means for controlling the flow of the contaminated air through the system.

2. The system of claim 1 further including a catalytic converter for removing residual ozone residing in the sterilized air.

3. The system of claim 1 further including circulation means for circulating the air in the surrounding environment to mix with the sterilized air emitted by the exhaust means.

4. The system of claim 1 wherein said germicidal chamber includes a first germicidal radiation source, wherein said ozone radiation source and said first germicidal radiation source correspond to ozone and germicidal sections of a single radiation bulb emitting radiation having different wavelengths at different sections of the bulb, wherein a first section of the bulb is disposed in the ozone chamber, and a second section of the bulb is disposed in said germicidal chamber.

5. The system of claim 4 wherein said germicidal chamber further includes a second germicidal radiation source comprising an independent radiation emitting bulb.

6. The system of claim 1 wherein said ozone radiation source and each said germicidal radiation source are independent radiation emitting bulbs.

7. The system of claim 1 wherein:

said ozone radiation source emits radiation having a wavelength of approximately 185 nanometers; and

each said germicidal radiation source emits radiation having a wavelength of approximately 254 nanometers.

8. The system of claim 1 further including:

ozone blower means for drawing ozone from said ozone chamber through said intake means; and

intake sterilization control means for determining the appropriate time to sterilize said intake means and initiating said sterilization of said intake means by powering down said system and activating said ozone blower means to direct the ozone through said intake means.

9. The system of claim 1 wherein said ozone chamber further includes a plurality of nested tubes surrounding said ozone radiation source wherein passages defined in spaces between each of said tubes form said tortuous or serpentine path.

10. The system of claim 9 wherein said plurality of tubes are eccentric or concentric.

11. The system of claim 9 wherein:

said ozone chamber includes upper and lower dividers defining the top and bottom boundaries of the ozone chamber;

each of said tubes alternately extends from said lower and upper dividers toward the opposing upper and lower destination divider, respectively, and terminates prior to reaching said destination divider such that the air flows to succeeding passages through links defined in spaces between the ends of the tubes and the respective destination divider; and

said air alternately flows in opposite longitudinal directions through said passages between succeeding tubes.

12. The system of claim 1 wherein the path includes an ozone generating region where the ozone is generated and a soaking region where the ozone mixes with the air, wherein the cross-sectional area of the soaking region is greater than the cross-sectional area of the ozone generating region such that the velocity of the air is reduced to provide time for, and enhance, the mixing of the ozone and the air.

13. The system of claim 9 wherein:

said ozone chamber includes upper and lower dividers defining the top and bottom boundaries of the ozone chamber;

each of said tubes extends from said lower to said upper dividers;

each of said tubes includes openings alternately disposed toward said upper and lower dividers such that air flows to succeeding passages through said openings;

a plurality of vortex generators are disposed between said tubes to churn the air and mix the air and ozone; and

said air alternately flows in opposite longitudinal directions through said passages between succeeding tubes.

14. The system of claim 1 wherein said germicidal chamber includes a reflective material disposed in the walls of the germicidal chamber to reflect, and increase the intensity of, the radiation emitted in the germicidal chamber.

15. An air sterilization system for receiving contaminated air from a surrounding environment, sterilizing the contaminated air, and recirculating the sterilized air back to the surrounding environment comprising:

intake means for receiving said contaminated air from said surrounding environment;

an ozone chamber including an ozone radiation source for irradiating said contaminated air to generate ozone to mix with the air and remove contaminants residing in the contaminated air;

a germicidal chamber including a germicidal radiation source for irradiating the air and ozone mixture to remove residual contaminants and ozone from the mixture resulting in sterilized air;

a catalytic converter for receiving the sterilized air from the germicidal chamber and removing ozone residing in the sterilized air;

exhaust means for returning the sterilized air back to the surrounding environment; and

blower means for controlling the flow of the contaminated air through the system.

16. An air sterilization system for receiving contaminated air from a surrounding environment, sterilizing the contaminated air, and recirculating the sterilized air back to the surrounding environment comprising:

intake means for receiving said contaminated air from said surrounding environment;

an ozone chamber including an ozone radiation source for irradiating said contaminated air to generate ozone to mix with the air and remove contaminants residing in the contaminated air;

a germicidal chamber including a germicidal radiation source for irradiating the air and ozone mixture to remove residual contaminants and ozone from the mixture resulting in sterilized air;

exhaust means for returning the sterilized air back to the surrounding environment; and

blower means for controlling the flow of the contaminated air through the system;

wherein said ozone and germicidal radiation sources comprise different sections of a single radiation emitting bulb emitting radiation having different wavelengths at different sections of the bulb.

17. The system of claim 16 wherein the germicidal chamber further includes a second germicidal radiation source comprising an independent radiation emitting bulb emitting radiation having the same wavelength as the radiation emitted by the germicidal radiation source to irradiate the air and ozone mixture to remove contaminants and ozone from the mixture.

18. In a system having an air inlet, ozone and germicidal chambers, and an exhaust for sterilizing contaminated air from a surrounding environment and recirculating the sterilized air back to the surrounding environment, a method of sterilizing the contaminated air comprising the steps of:

(a) irradiating said contaminated air in said ozone chamber to generate ozone to remove contaminants residing in said contaminated air;

(b) forming a tortuous or serpentine path in said ozone chamber to decrease air flow velocity and enhance distribution of ozone in the flowing air to remove the contaminants; and

(c) irradiating the air and ozone mixture in said germicidal chamber to remove residual contaminants and ozone from the mixture resulting in sterilized air.

19. The method of claim 18 further including the step of:

(d) removing ozone residing in said sterilized air via a catalytic converter.

20. The method of claim 18 further including the step of:

(d) circulating the air in the surrounding environment such that the air in the surrounding environment mixes with the sterilized air to increase the sterilization rate of the surrounding environment.

21. The method of claim 18 wherein:

step (a) further includes:

(a.1) irradiating said contaminated air via radiation having a first wavelength emitted from a first section of a radiation emitting bulb; and

step (c) further includes:

(c.1) irradiating the air and ozone mixture via radiation having a second wavelength emitted from a second section of said bulb;

wherein said first and second wavelengths are different and said first and second sections are disposed in said ozone and germicidal chambers, respectively.

22. The method of claim 21 wherein step (c.1) further includes:

(c.1.1) irradiating said contaminated air via radiation having said second wavelength emitted from an independent radiation emitting bulb.

23. The method of claim 18 wherein:

step (a) further includes:

(a.1) irradiating said contaminated air via an ozone radiation source; and

step (c) further includes:

(c.1) irradiating the air and ozone mixture via at least one germicidal radiation source;

wherein said ozone and each germicidal radiation source are independent radiation emitting bulbs.

24. The method of claim 18 wherein:

step (a) includes:

(a.1) irradiating said contaminated air with radiation having a wavelength of approximately 185 nanometers; and

step (c) includes:

(c.1) irradiating the air and ozone mixture with radiation having a wavelength of approximately 254 nanometers.

25. The method of claim 18 further including the step of:

(d) periodically sterilizing the air inlet by directing ozone from said ozone chamber through said air inlet.

26. The method of claim 18 wherein step (b) further includes:

(b.1) forming said tortuous or serpentine path to include a plurality of nested tubes that surround an ozone radiation source disposed within said ozone chamber wherein passages formed in spaces between each of said tubes define said path.

27. The method of claim 26 wherein step (b.1) further includes:

(b.1.1) forming said tortuous or serpentine path to include a plurality of eccentric or concentric tubes.

28. The method of claim 26 wherein step (b.1) further includes:

(b.1.1) forming said tortuous or serpentine path such that said air and ozone alternately flow in opposite longitudinal directions in the passages between succeeding tubes to control air velocity and enable the ozone to mix with the air.

29. The method of claim 26 wherein step (b.1) further includes:

(b.1.1) forming said tortuous or serpentine path such that said path includes an ozone generating region where the ozone is generated and a soaking region where the ozone mixes with the air wherein the cross-sectional area of the soaking region is greater than the cross-sectional area of the ozone generating region to reduce air velocity to provide time for, and enhance, the mixing of the ozone with the air.

30. The method of claim 18 wherein step (c) further includes:

(c.1) reflecting radiation emitted in said germicidal chamber to increase the intensity of the radiation via a reflective material disposed in the walls of the germicidal chamber.

31. In a system having an air inlet, ozone and germicidal chambers, and an exhaust for sterilizing contaminated air from a surrounding environment and recirculating the sterilized air back to the surrounding environment, a method of sterilizing the contaminated air comprising the steps of:

(a) irradiating said contaminated air in said ozone chamber to generate ozone to mix with, and remove contaminants residing in, said contaminated air;

(b) irradiating the air and ozone mixture in said germicidal chamber to remove residual contaminants and ozone from the mixture resulting in sterilized air; and

(c) removing ozone residing in the sterilized air via a catalytic converter after step (b).

32. In a system having an air inlet, ozone and germicidal chambers, and an exhaust for sterilizing contaminated air and recirculating the sterilized air back to the surrounding environment, a method of sterilizing the contaminated air comprising the steps of:

(a) irradiating said contaminated air in said ozone chamber via an ozone radiation source to generate ozone to mix with, and remove contaminants residing in, said contaminated air;

(b) irradiating the air and ozone mixture in said germicidal chamber via a germicidal radiation source to remove residual contaminants and ozone from the ozone mixture resulting in sterilized air;

wherein said ozone and germicidal radiation sources comprise different sections of a single radiation emitting bulb emitting radiation having different wavelengths at different sections of the bulb.

33. The method of claim 32 wherein step (b) further includes:

(b.1) irradiating the mixture by an additional independent radiation emitting bulb emitting radiation having the same wavelength as the germicidal radiation source.

34. The method of claim 18 wherein step (b) further includes:

(b.1) forming said tortuous or serpentine path to include a plurality of plates separated by a predetermined distance wherein passages formed in spaces between said plates define said path.

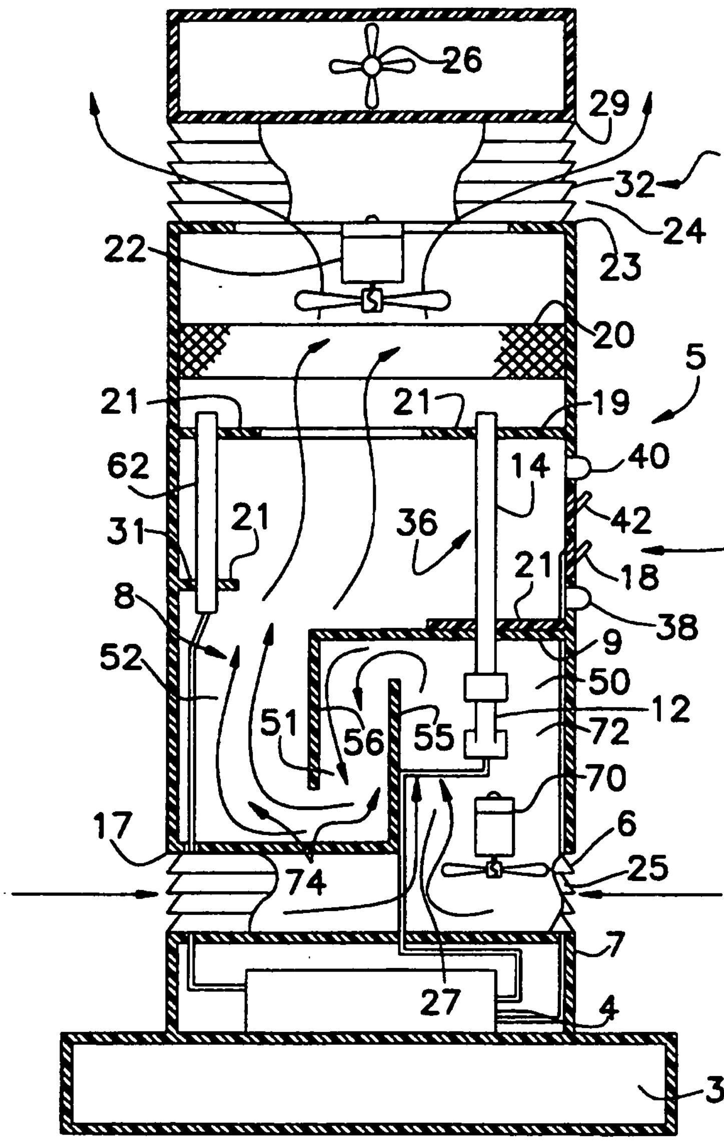
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FIG.1a

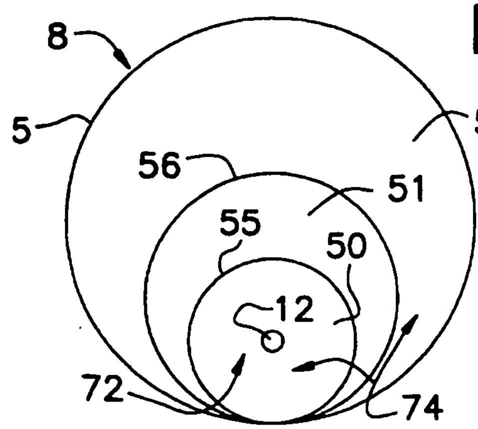
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FIG.1b

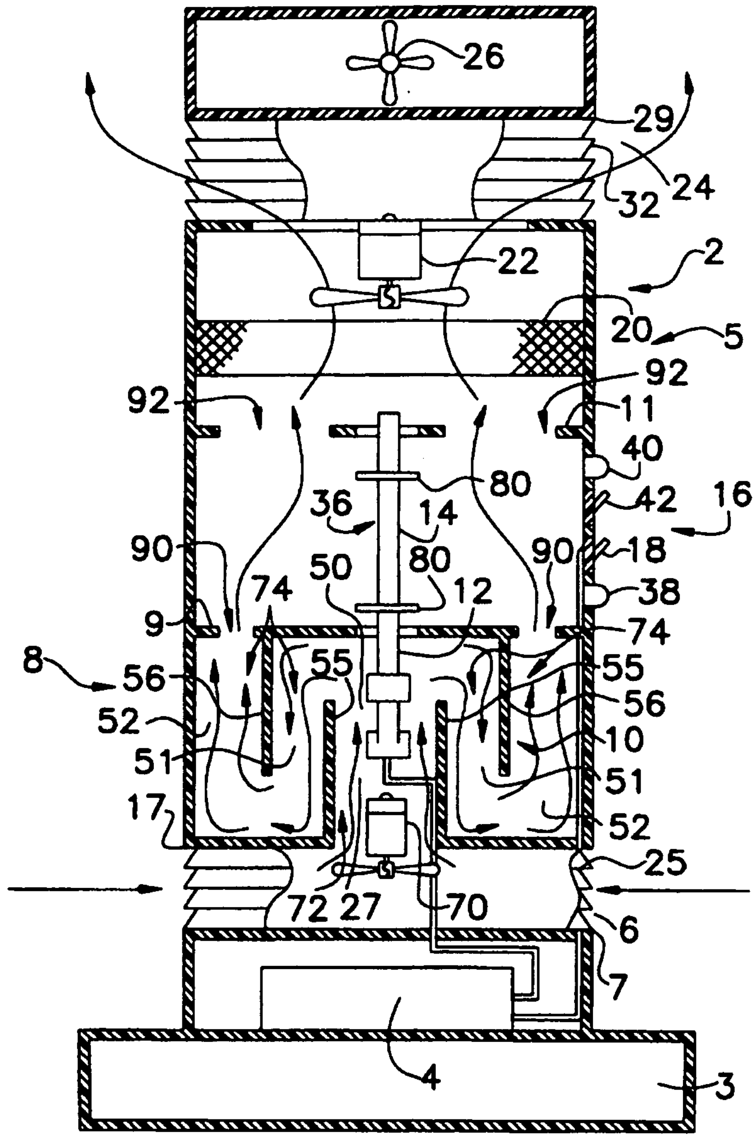
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FIG.2a

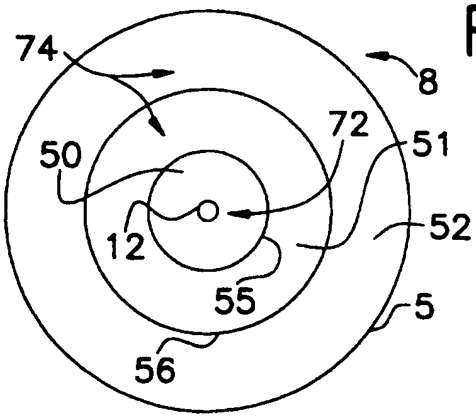
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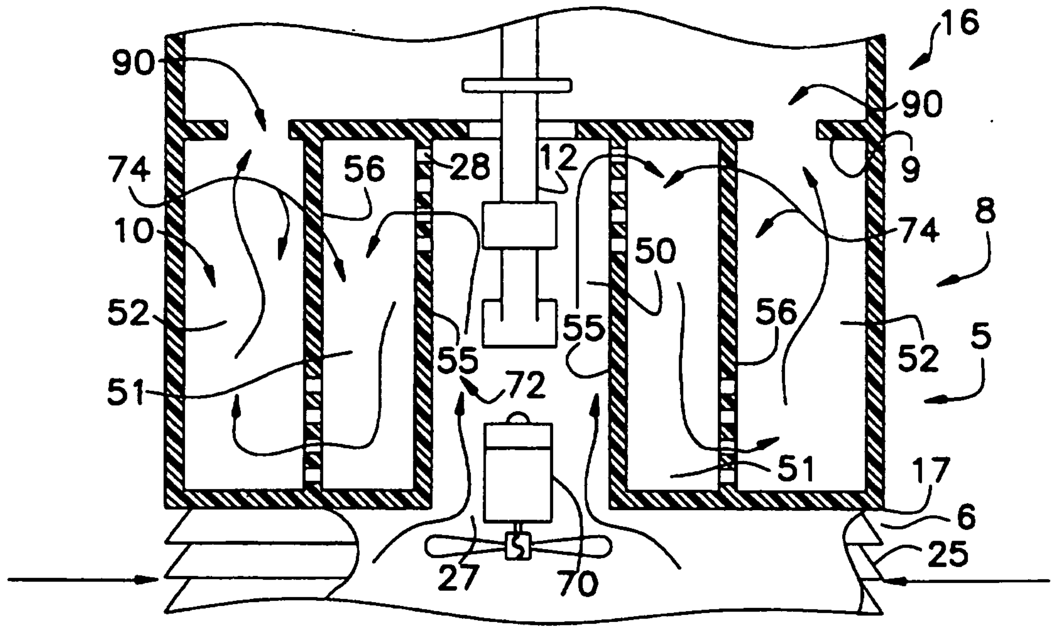
FIG.2b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56
52
5
52
55
72
51
51
17
6
25
27
70

FIG.3a

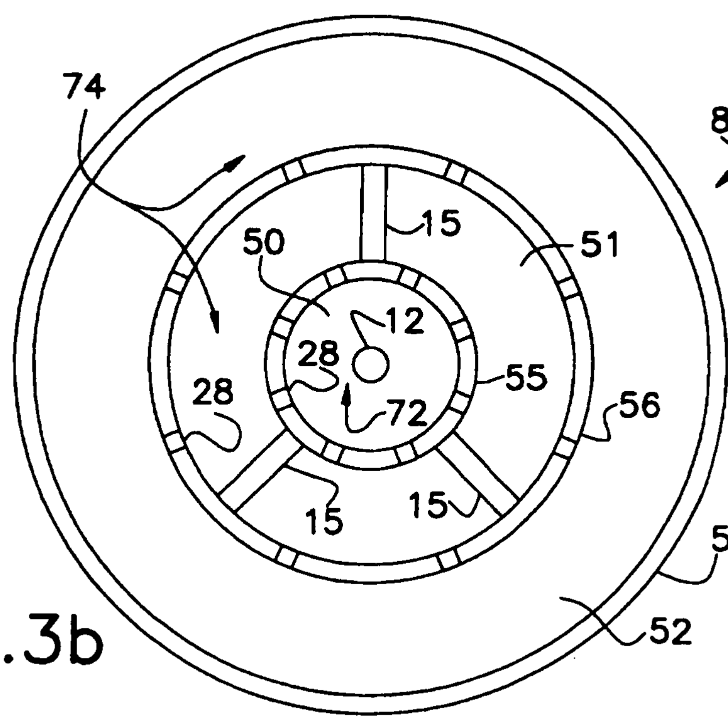

74
8
15
50
51
12
28
55
28
72
56
15
15
5
52

FIG.3b

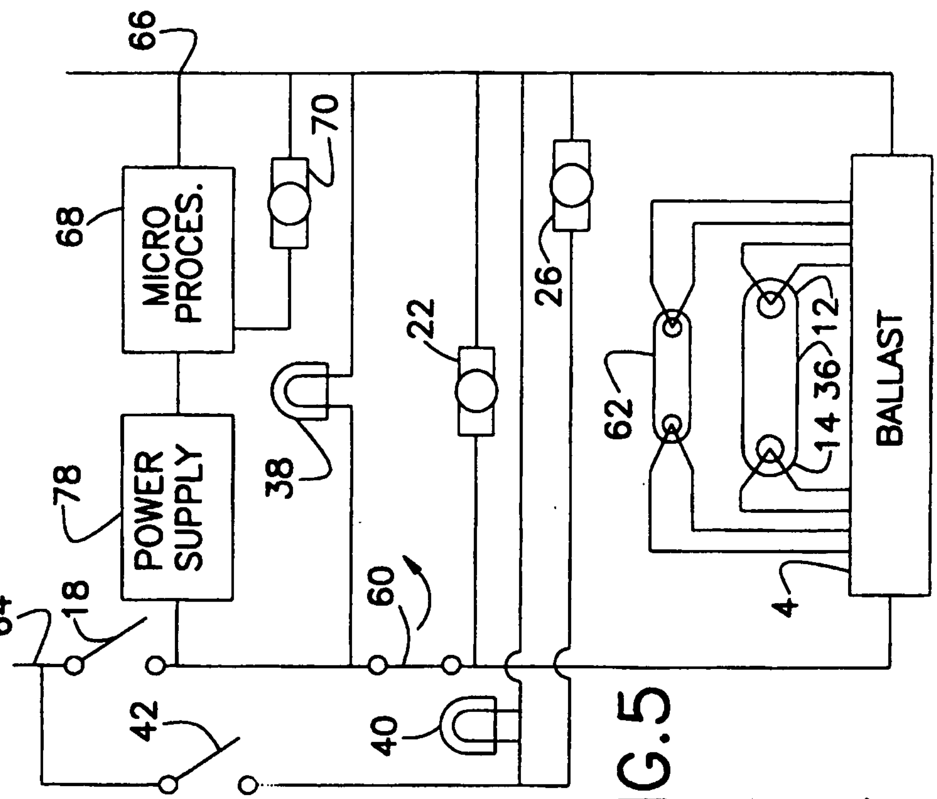
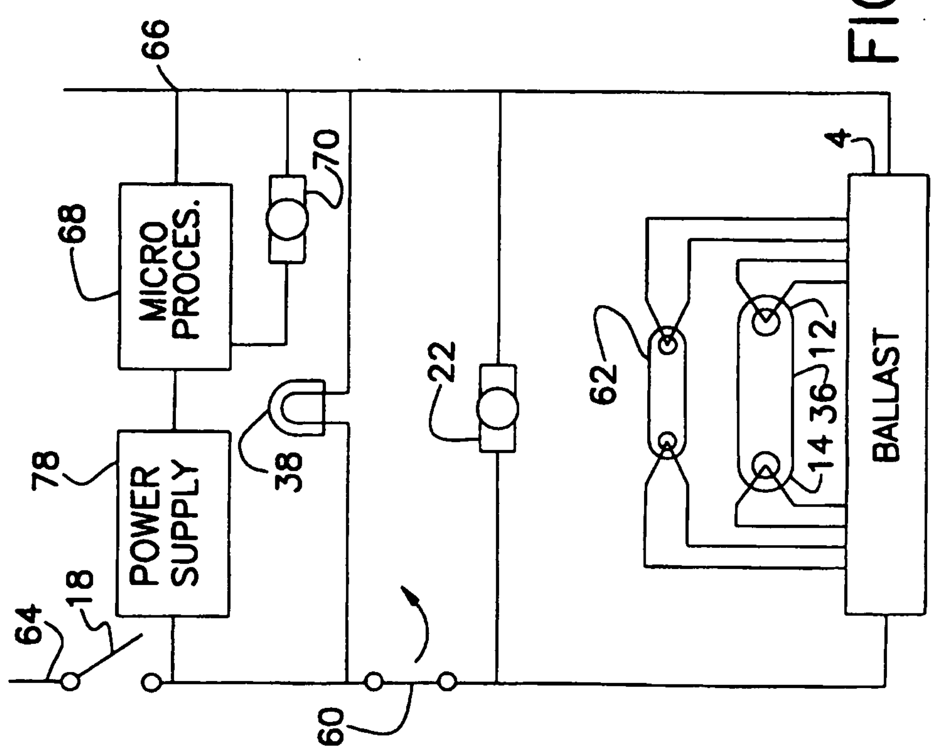

66
70
68
MICRO PROCES.
POWER SUPPLY
78
64
18
38
22
26
60
42
40
62
14 36
12
BALLAST
4

FIG.5

FIG.4


66
70
68
MICRO PROCES.
POWER SUPPLY
78
64
18
38
22
4
62
14 36
12
BALLAST
60

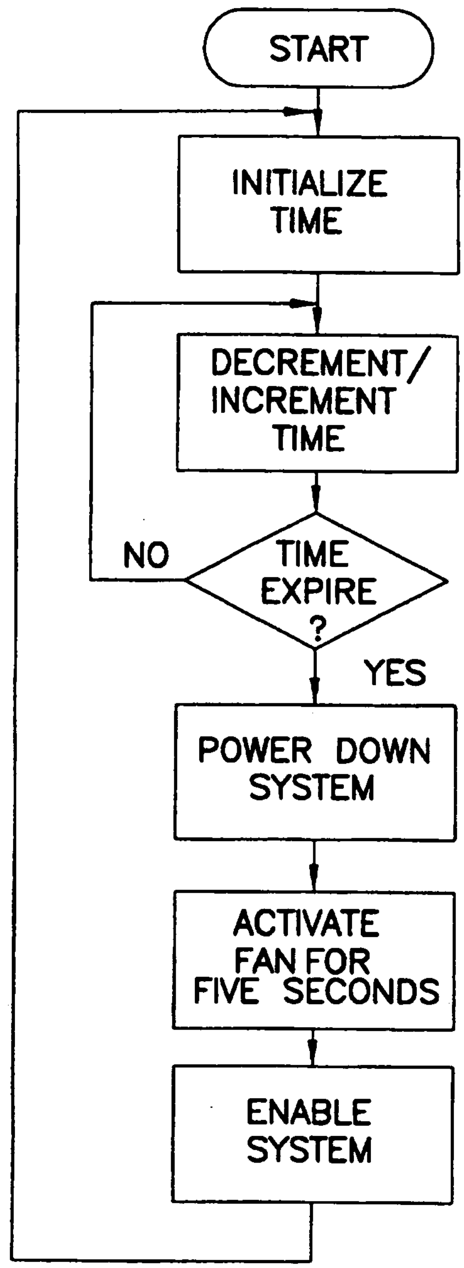

START
INITIALIZE TIME
DECREMENT/ INCREMENT TIME
NO
TIME EXPIRE ?
YES
POWER DOWN SYSTEM
ACTIVATE FAN FOR FIVE SECONDS
ENABLE SYSTEM

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03732

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B01D 53/00
US CL :204/157.3, 158.20; 422/121
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 204/157.3, 158.20; 422/121; 423/219

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,015,442 A (HIRAI) 14 May 1991 (14.05.91), column 4, lines 20-40.	1-3,6-7,12, 14-15,18-20,23-24, 30-31
Y	US 3,486,308 A (BURT) 30 December 1969 (30.12.69), column 1, lines 25-31 and column 2, lines 35-40.	34

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 10 MAY 1997	Date of mailing of the international search report 24 JUL 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer for EDNA WONG Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03732

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS, STN
terms: sterilization, air, ozone, germicidal, radiation, blower, nested tubes, catalytic converter, serpentine path